

# INF2178 - Assignment 4 (Mingli Wang)

## Introduction

This study investigates the trajectories of brain volume changes in individuals with and without dementia, focusing specifically on normalized whole brain volume (nWBV) and estimated total intracranial volume (eTIV). Our research question, **"Do patients with dementia exhibit different trajectories of brain volume changes over time compared to nondemented individuals?"** aims to identify if dementia significantly influences the rate and pattern of brain volume reduction. Through mixed-effects ANOVA and statistical power analysis, we explore the potential disparities in brain structure alterations, seeking to enhance our understanding and management of dementia.

The dataset for this study comprises MRI data from a longitudinal study designed to explore the impact of dementia on brain volume changes over time. It includes measurements from 294 observations, representing 150 unique subjects who have undergone one or more MRI scans. Each subject is classified into one of three groups: 'Demented', 'Nondemented', or "Converted" based on their clinical diagnosis.

## Data Cleaning and Wrangling

The dataset comprises several columns but for our analysis focused on the trajectories of brain volume changes, the most relevant columns are:

Column name/Feature	Description
Group	Indicates whether the subject is 'Demented' or 'Nondemented'
Visit	The visit number for the MRI scan
MR Delay	The delay time between the first and the subsequent visit in days
M/F	Gender of the subject
Age	Age of the subject at the time of the visit
eTIV	Estimated Total Intracranial Volume
nWBV	Normalized Whole Brain Volume

### Empty Values

The dataset does not contain any missing values for the key variables of eTIV and nWBV, ensuring a robust dataset for analysis.

### Data Wrangling

For the "Subject ID" column which is used to identify the research participants, the ID is converted to integers from strings to prepare it for mixed effect ANOVA analysis. For example, "OAS2\_0184" is converted to "184".

# Exploratory Data Analysis

We will start the analysis with an EDA by checking the summary statistics of the variables that are of concern, the means of eTIV and nWBV of different groups are also examined comparatively. The procedure has revealed the following insights:

- The mean nWBV for the demented group was 0.719 and for the nondemented group was 0.742, suggesting a potential difference in brain volume between these two groups.
- The mean eTIV was similar between the demented (1483.62 mm<sup>3</sup>) and nondemented groups (1481.38 mm<sup>3</sup>), indicating that total intracranial volume does not significantly differ based on dementia status.

	Visit	MR Delay	Age	eTIV	nWBV
count	294.00	294.00	294.00	294.00	294.00
mean	1.49	349.79	76.41	1478.85	0.73
std	0.50	400.74	7.61	176.56	0.04
min	1.00	0.00	60.00	1106.00	0.65
25%	1.00	0.00	71.00	1347.25	0.70
50%	1.00	0.00	76.00	1461.50	0.73
75%	2.00	671.50	81.00	1569.00	0.76
max	2.00	1707.00	98.00	2004.00	0.84

A barplot of the observations in "Group" differentiated by "Visit" is created to visualize the count of participants that are non-demented, demented, and converted. The demented group has slightly fewer observations than the non-demented group.

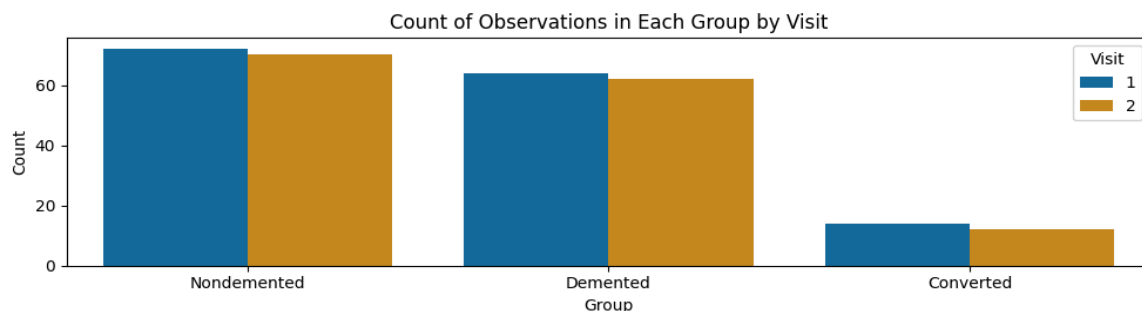
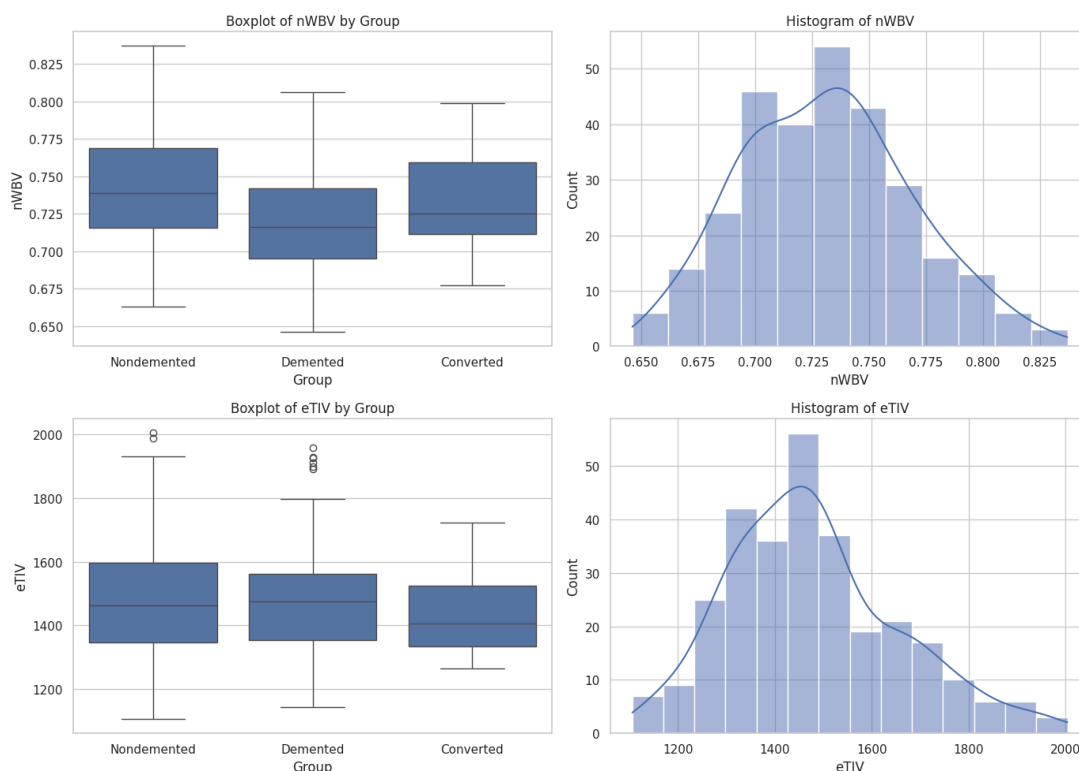


Figure 1. Barplot for the count of each group by visit

Next, we plotted boxplots for nWBV and eTIV by group, and histograms for nWBV and eTIV respectively. As shown in the plots, both nWBV and eTIV are approximately normally distributed.



## Effects of Normalized Whole Brain Volume (nWBV)

To answer our research question, we will examine the effects of nWBV and eTIV on dementia individually before concluding. This section will first examine the effect of nWBV by visit and group using mixed effect ANOVA.

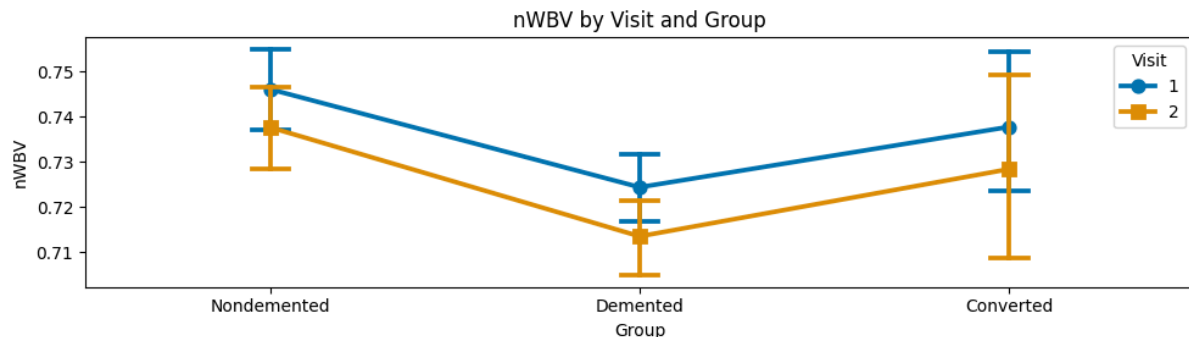


Figure 3. Pointplot for nWBV by visit and group

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ANOVA SUMMARY  
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Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	0.034	2	141	0.017	6.712	0.002	0.087	nan
Visit	0.007	1	141	0.007	94.251	0.000	0.401	1.000
Interaction	0.000	2	141	0.000	1.534	0.219	0.021	nan

Figure 4. Mixed effect ANOVA summary of nWBV by visit and group

The mixed ANOVA results indicate significant effects of both Group and Visit on normalized whole brain volume (nWBV), though their interaction is not significant. Specifically, the Group effect is significant ( $p = 0.002$ ) with a medium effect size (partial eta squared = 0.087), suggesting that different groups exhibit significantly different mean nWBV. The Visit effect is highly significant ( $p < 0.001$ ) with a large effect size (partial eta squared = 0.401), indicating a substantial change in nWBV across visits. However, the interaction between Group and Visit is not significant ( $p = 0.219$ ), with a small effect size (partial eta squared = 0.021), which means the pattern of nWBV change over visits does not vary significantly between groups.

### Assumption Checks:

- Sphericity:  $p\text{-value} = 1$  ( $> 0.05$ ), the assumption is satisfied.
- Normality: all combinations have a  $p\text{-value} > 0.05$ , the assumption is satisfied.
- Homogeneity:  $p\text{-value} = 0.388$  ( $> 0.05$ ), the assumption is satisfied.

## Effects of Estimated Total Intracranial Volume (eTIV)

The second mixed-effects ANOVA analysis on the estimated total intracranial volume (eTIV) revealed that the effect of Visit is significant ( $p = 0.003$ ) with a moderate effect size, indicating significant within-subject changes in eTIV over time. However, the effect of Group on eTIV was not significant ( $p = 0.743$ ), showing no substantial differences in eTIV across different groups. Additionally, the interaction between Group and Visit also lacked

significance ( $p = 0.438$ ), suggesting that the change in eTIV across visits does not vary significantly among the groups.

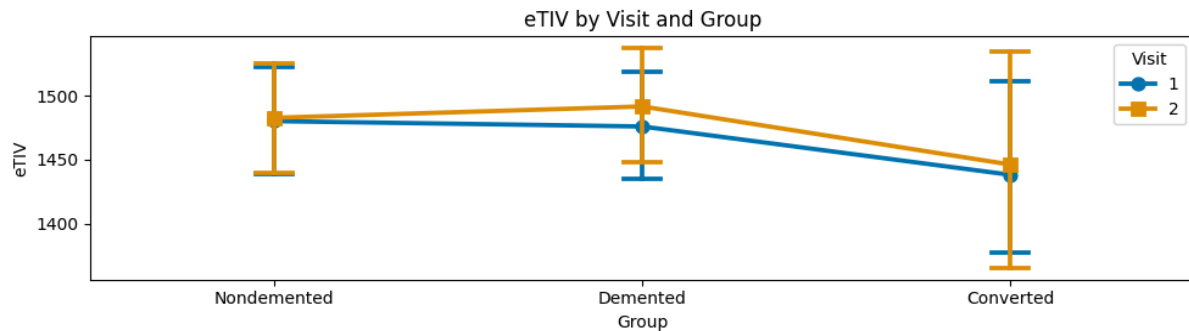
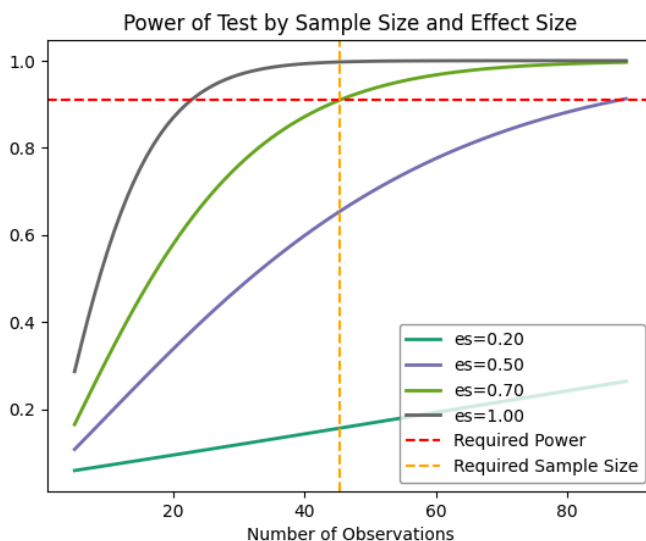


Figure 5. Pointplot for eTIV by visit and group

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ANOVA SUMMARY  
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Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	37424.708	2	141	18712.354	0.297	0.743	0.004	nan
Visit	5573.920	1	141	5573.920	9.225	0.003	0.061	1.000
Interaction	1004.783	2	141	502.392	0.831	0.438	0.012	nan

Figure 6. Mixed effect ANOVA summary of eTIV by visit and group



## Sample Size and Power Plot

The test aims for an effect size of 0.7, a power of 0.91, and the alpha level is set to 0.05. Based on these parameters and using the power analysis, we determined that the sample size is 45.451, rounding up to 46 samples.

Figure 7. Power of test by sample size and effect size.

## Conclusion

The ANOVA analyses for normalized whole brain volume (nWBV) and estimated total intracranial volume (ETIV) indicate that although brain volume changes significantly over time for both demented and nondemented individuals, the rate of these changes does not differ between the two groups. This suggests that dementia status does not influence the trajectory of brain volume changes over time, despite differences in brain volume levels. While the two metrics can be used to support the diagnosis of dementia, unfortunately, they cannot be used to predict dementia.